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Bangladesh J. Sci. Ind. Res. **46(3)**, 339-342, 2011

BCSIR

BANGLADESH JOURNAL OF SCIENTIFIC AND INDUSTRIAL RESEARCH

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Optimization of Aeration Technique for the Reduction of Impurities (Corrosive Gases) from Biogas.

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Abstract

Biogas, produced from organic waste through anaerobic digestion (AD), is mainly composed of methane (CH_4) and carbon dioxide (CO_2) with smaller amount of hydrogen sulfide (H_2S) and nitrogen (N_2). Trace amount of some other gases are occasionally present in biogas. For electricity generation from biogas, reduction of H_2S is necessary because it is toxic and corrosive to most of the equipments. Reduction of Hydrogen Sulfide (H_2S) from poultry based biogas (normally it contents 1500~2500 ppm) can be done by dosing air/oxygen to the main digester during the digestion process. Two methods of air injection technique have been followed for optimization of the process. Firstly two hour interval air injection and secondly air injection based on percentage of hourly gas production. The optimum air percentage to minimize H_2S should be at least 3.00%. After aeration H_2S level comes to the desired level (<50ppm) within 1.5-2.0 hours and remains constant up to 7-9 hours and biogas can be used for effective power generation. A complete aeration system has been developed which is simple and cost effective for H_2S reduction to the desired level from poultry based biogas plant. This system can be applied for any size of poultry based biogas plant for effective power generation.

Key words: Anaerobic digestion, Hydrogen Sulfide (H_2S), Aeration, Biogas digester, Power generation

Introduction

Biogas consists mainly of methane (CH_4) and carbon dioxide (CO_2), with smaller amounts of water vapor and trace amounts of hydrogen sulfide (H_2S), and other impurities. Various degrees of gas processing are necessary depending on the desired gas utilization process. Hydrogen sulfide is typically the most problematic contaminant because it is toxic and corrosive to most equipment (jerry 2008). Additionally, combustion of H_2S leads to sulfur dioxide emissions, which have harmful environmental effects. Removing H_2S as soon as possible is recommended to protect downstream equipment, increase safety, and enable possible utilization of more efficient technologies such as gas generator and micro turbines. Generally biogas has the following composition shown in Table I (Haque, S. M. *et al.,* 2001).

Bangladesh has a great potential for biogas production in respect of the availability of raw materials and climatic conditions. There are more than 0.1 million poultry farms in Bangladesh from which 191 million cube meter biogas can be produced which can be used for power generation (Khandelwal K.C. and Mahdi S.S., 1993). But biogas from poultry farms contains more H_2S which is corrosive for engine. For better engine operation it needs to minimize H_2S level below 50 ppm.

Table I: Biogas composition and contaminants

Major Component	
Methane (CH_4)	60 - 70%
Carbon dioxide (CO_2)	30 - 40 %
Nitrogen (N_2)	1.0 - 1.5 %
Oxygen (O_2)	0.1 - 1.5 %
Hydrogen (H_2)	1.3 - 1.7 %
Hydrogen Sulfide (H_2S)	1500 - 2500 ppm
Mercaptanes	0 - 100 ppm
Trace components	
Siloxane	0 - 100 mg/m³
Halogenated Hydrocarbon	0 - 100 mg/m³
Moisture	Trace

The most common commercial methods for H_2S removal are, Air/oxygen dosing to digester biogas, Iron-chloride dosing

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to digester slurry, Iron sponge, Iron oxide pellets, Activated carbon, Water scrubbing, NaOH scrubbing, Biological removal on a filter bed, Air stripping and recovery. The simplest method of the desulphurization is the addition of air/oxygen directly into the digester or in a storage tank serving at the same time as gas holder. Air is carefully admitted to the digester or biogas storage tank at levels corresponding to 2-6% air in biogas. It is believed effectiveness is based on biological aerobic oxidation of H_2S to elemental sulfur and sulfates. Inoculation is not required, as *Thiobacillus* species are naturally occurring at aerobic liquid-manure-wetted surfaces (Steven, 2003). Depending on the temperature, the reaction time, the amount and place of the air added the hydrogen sulfide concentration can be reduced by 95% to less than 50 ppm.

Table II: Physical, Chemical and Safety Characteristics of Hydrogen Sulfide

Characteristics	Property
Molecular Weight	34.08
Specific Gravity (relative to air)	1.192
Auto Ignition Temperature	250^{o}C
Explosive Range in Air	4.5 to 45.5 %
Odor Threshold	0.47 ppb
8-hour time weighted average (TWA) (OSHA)	10ppm
15-minute short term exposure limit (STEL) (OSHA)	15ppm
Immediately Dangerous to Life of Health (IDLH) (OSHA)	300ppm

Source: OSHA (2002), Occupational Safety and Health Administration, www.OSHA.gov

The main objectives of this research work is to optimize aeration technique to reduce H_2S from poultry based biogas, to estimate the percentage of Hydrogen sulfide in biogas and optimization of injected air and time interval suitable for electricity generation.

Experimental Methodology

Necessary arrangement for biogas production and aeration system in the laboratory has been set up. For field level experiment one existing biogas plant (1.27 m^3 gas production/day) of IFRD has been repaired and aeration arrangement has been established (Fig. 1). The plant has been charged by poultry dropping with necessary water mix and the gas analysis has been started after sufficient gas production. There are two sets of aeration technique have been followed in this experiment. i) Two hour interval air injection and ii) Air injection based on percentage of gas production. Collection of sample and analyze through Orsat analyzer and Gas analyzer. Optimization of injected air amount and time interval is based on analysis.

With a view to reducing H_2S from poultry based biogas plant for electricity generation, a complete air injection arrangement system in biogas plant has been developed and setup which shown in Figure 1 given below-

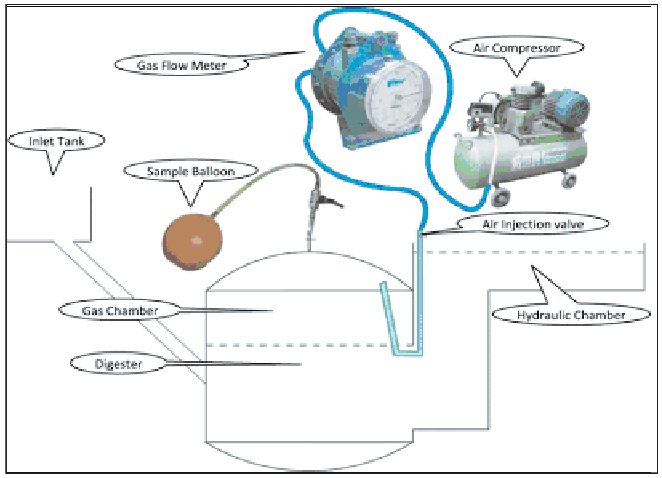


Fig. 1: Aeration arrangement for H_2S reduction

Test procedure for H_2S reduction

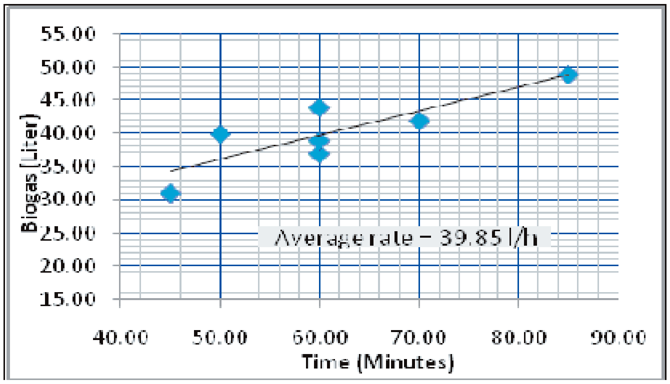
Technique A

Two hour interval air injection into the plant according to the following schedule shown in Table III.

Table III: Aeration schedule for H_2S reduction

Time	Steps	Activity
9:40	1st Step	Test biogas composition
9:50	2nd Step	Vent out biogas from the plant
9:55	3rd Step	Inject 5.33 liter air
10:00	4th Step	Test biogas composition
12:00	5th Step	Test biogas composition
12:00	6th Step	Inject 5.33 liter air
12:05	7th Step	Test biogas composition
14:00	8th Step	Test biogas composition
14:00	9th Step	Inject 5.33 liter air
14:05	10th Step	Test biogas composition
16:00	11th Step	Test biogas composition
16:05	12th Step	Vent out biogas from the plant
16:10	13th Step	inject 5.33 liter air

During this experiment the gas production rate on an average was found 39.85 liter per hour which shown in Graph-1.



Graph 1: Gas production rate

H_2S reduction has been obtained by addition air at two hours interval which has shown in Table IV.

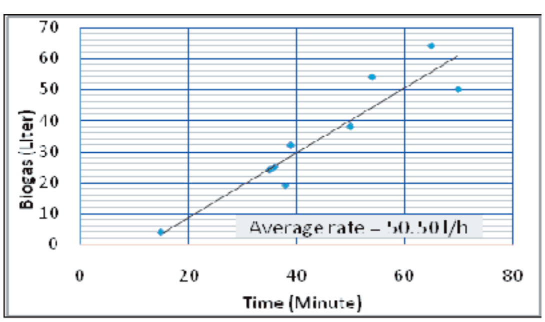
Table IV: Two hours interval aeration H_2S reduction

Time	Air (l)	Biogas (l)	H_2S (ppm)
10:05 AM	5.26	0.00	> 500
10:15 AM		3.40	> 500
12:00 PM		35.70	106.00
12:00 PM	5.30	0.00	
12:10 PM		3.40	71.00
2:00 PM		37.40	18.00
2:00 PM	5.20	0.00	
2:10 PM		3.40	9.00
4:00 PM		37.40	3.00

Single Air injection based on percentage of gas production.

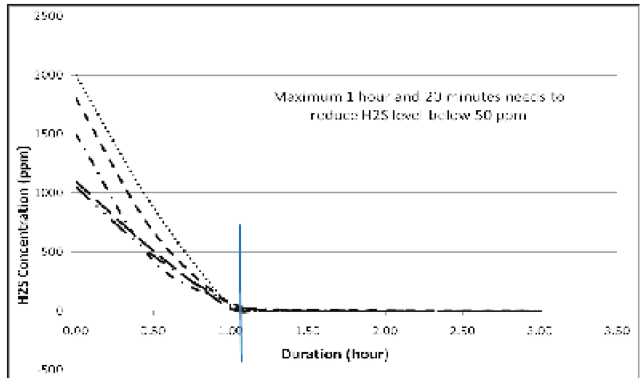
Technique B

During experiment, the plant was in continuous charging condition and the gas production rate has been found to be 50.50 liter per hour shown in the Graph 2.



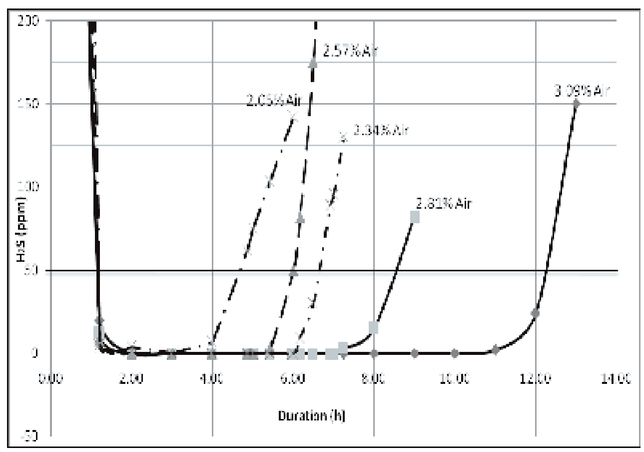
Graph 2: Gas production rate

Significant H_2S reduction have been achieved by addition of air to biogas and time needs to reduce initial level down to below 50 ppm is about 1 hour and 20 minutes shown in the Graph 3.



Graph 3: Time to reduce H_2S

The duration to remain H_2S concentration under the desired level varies with addition of different percentage of air to biogas in the plant which are shown in the Graph 4.



Graph 4: Duration of below desired level of H_2S by aeration with different percentage of air

Biogas composition of experimental poultry based biogas plant before and after aeration system has been determined and shown in the Table V.

Table V: The composition of biogas before and after aeration

S/N	Component	Before aeration	After aeration
1.	CH_4	68.40%	66.50%
2.	CO_2	27.80%	26.20%
3.	H_2S	1850 ppm	<50 ppm
4.	O_2	0.80%	1.80%
5.	N_2	2.10%	4.80%

Results and Discussion

Throughout the research, there are two techniques have been applied for H_2S reduction from poultry based biogas.

In Technique A, two hour interval air injection into the plant has been carried out according to the schedule shown in Table I. At that time, gas production rate was 39.85 liter per hour (shown in Graph 1). From the Table II, it was found that H_2S level reduced up to minimum (<50 ppm) after four hours of initial air injection.

In Technique B, single air injection has been carried out based on percentage of gas production. During experiment, the plant was in continuous charging condition and the gas production rate has been found around 50.50 liter per hour (Shown in Graph 2). Significant H_2S reduction has been achieved by addition of different percentage of air (2.05-3.09%) to biogas plant which are shown in the Graph 3. From the Graph 3 it is found that the duration of the H_2S level remains minimum depending on the percentage of air injection. At this percentage of air, H_2S level comes to the desired level (<50ppm) within 1.5-2.0 hours and remains constant up to 7-9 hours and biogas can be used for effective power generation.

Finally the Table IV shows that H_2S concentration in poultry based biogas has been found to be 1850 ppm to less than 50 ppm before and after aeration respectively.

Conclusion

Generally H_2S concentration in poultry based biogas varies from 1500-2500 ppm. A complete aeration system has been developed which is simple and cost effective for H_2S reduction to the desired level from poultry based biogas plant. The optimum air percentage to minimize H_2S should be at least 3.0%. After aeration H_2S level comes to the desired level (<50ppm) within 1.5-2.0 hours and remains constant up to 7-9 hours and biogas can be used for effective power generation. This system can be applied for any size of poultry based biogas plant for effective power generation.

Compare with the chemical treatment (Haque *et al.,* 2001) the developed technique is cheaper, easier and user friendly for reduction of Hydrogen Sulfide from biogas.

Acknowledgements

Foremost, Authors would like to express our sincere gratitude to Mr. Jasim Uddin Chowdhury, director IFRD, BCSIR, Dhaka for his continuous support and encouragement for carrying out this research work.

Authors would like to thank German Technical Cooperation (gtz) for financial support to complete this research project.

Besides this, Authors would like to thank laboratory technicians K. M. Abul Kalam, Md. Nasu Miah, Md. Mozzammel Hossain and Md. Abdul Hamid for their sincere assistance.

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Received : April 04, 2010;
Accepted : January 11, 2011